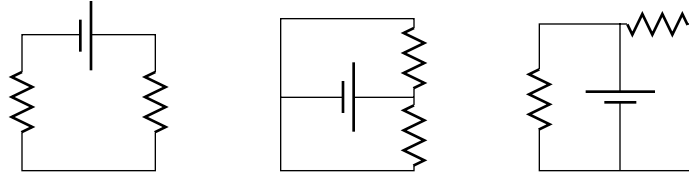
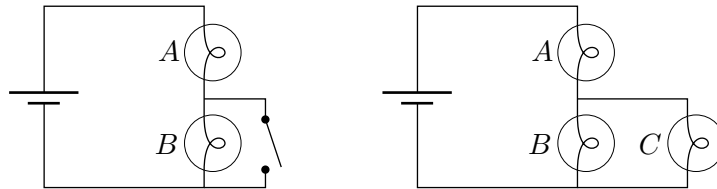


Problem Set 5
(due Thursday, Sept. 23)

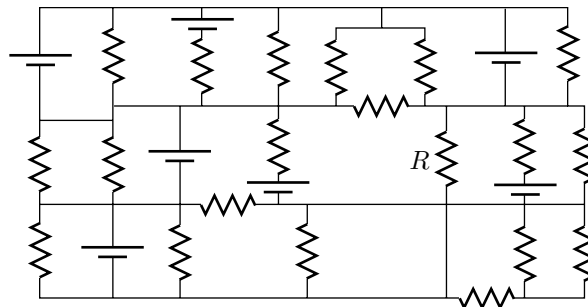
1. For each circuit shown below, are the resistors connected in series, in parallel, or neither?



2. You are to connect two resistors, R_1 and R_2 , with $R_1 > R_2$, to a battery, first individually, then in series, then in parallel. Rank those arrangements according to the amount of current through the battery, greatest first.
3. Are the headlights of a car wired in series or in parallel? How can you tell?
4. Shown below (left) are two lightbulbs wired in series with a battery. What happens to the brightness of each bulb when the switch is closed, “short-circuiting” bulb B?
5. The figure below (right) shows three light bulbs connected to a battery. Suppose now that you unscrew bulb C. What happens to the brightness of bulbs A and B?



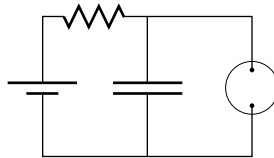
6. You need a $45\text{-}\Omega$ resistor, but the stockroom has only $20\text{-}\Omega$ and $50\text{-}\Omega$ resistors (in unlimited numbers). How can you combine them to get what you need? What can you do if you need a $35\text{-}\Omega$ resistor?
7. In the maze of batteries and resistors shown below, each battery has a voltage of 4 V and each resistor has a resistance of $4\text{ }\Omega$. What is the current through resistor R ? (Hint: If you can find the proper loop through the maze, you can answer the question very easily.)



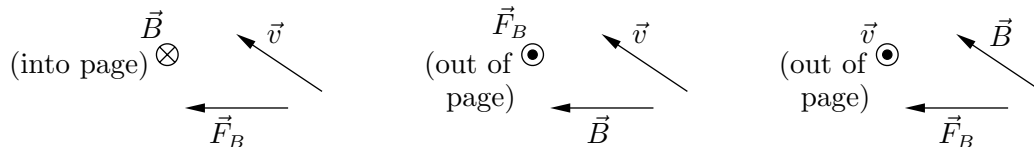
8. The starting motor of an automobile is turning too slowly, and the mechanic has to decide whether to replace the motor, the cable, or the battery. The manufacturer’s manual says that

the 12 V battery should have no more than $0.020\ \Omega$ internal resistance, the motor no more than $0.20\ \Omega$ resistance, and the cable no more than $0.040\ \Omega$ resistance. The mechanic turns on the motor and measures 11.4 V across the battery, 3.0 V across the cable, and a current of 50 A. What is the actual resistance of each of the three components? Which part is defective?

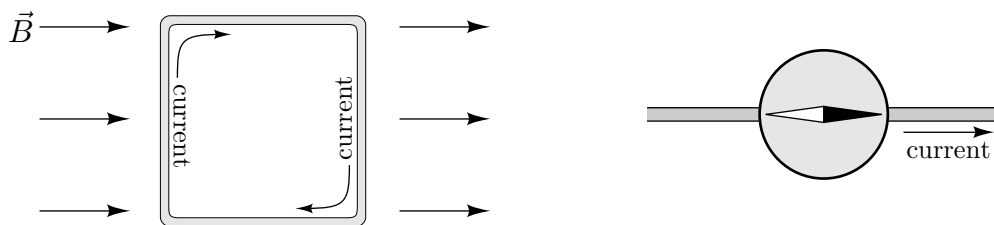
- A $1000\ \mu\text{F}$ capacitor is charged up to 12 V using a battery. The battery is then disconnected, and the capacitor is discharged through a $4\ \text{k}\Omega$ resistor. As the capacitor discharges, the voltage across its two terminals is monitored with a voltmeter. Sketch a graph of this voltage as a function of time, calibrating both axes with numbers. (Hint: First calculate the time constant of the circuit.)
- The figure below shows the circuit of a flashing lamp, like those attached to barrels at highway construction sites. The fluorescent lamp (which has negligible capacitance) is connected in parallel across the capacitor of an RC circuit. There is current through the lamp only when the voltage difference across it reaches its “breakdown voltage” of 72 V; in this event, the capacitor discharges completely through the lamp and the lamp flashes briefly. Suppose that you want the lamp to flash twice per second. If the battery voltage is 95 V and the capacitance of the capacitor is $0.15\ \mu\text{F}$, what should be the resistance of the resistor? (Hint: Ignore the lamp while you analyze the rest of the circuit. First analyze it qualitatively, sketching a graph of the voltage across the capacitor (or across the resistor) as a function of time. The equation for any such graph will involve a factor of $e^{-t/RC}$, the same factor as in a simple RC circuit with no battery.)



- Suppose you have a sensitive ammeter (called a *galvanometer*), with a resistance of $75\ \Omega$. The needle is deflected to full scale by a current of 1.5 mA passing through the galvanometer. You wish to use this meter to measure much larger currents, up to 1.0 A. To do this you place a resistor (called a *shunt resistor*) in parallel with the galvanometer. What should be the value of the shunt resistor?
- The figure below shows three situations in which a positively charged particle with velocity \vec{v} moves through a uniform magnetic field \vec{B} and experiences a magnetic force \vec{F}_B . In each situation, determine whether the orientations of the vectors are physically reasonable.



- Suppose that a charged particle moves in a straight line through some region of space. Can you conclude that the magnetic field in this region is zero? Explain.
- The figure on the next page (left) shows a square loop of wire in which an electric current is circulating clockwise. A magnetic field, which points to the right, fills the region. Determine the direction of the magnetic force exerted by the field on each segment of the loop. If the loop is free to move, what will it do?



15. A compass rests on top of a straight wire, as shown above (right). When there is no current flowing through the wire, the compass needle points to the right. Suppose now that a current, traveling to the right, is put through the wire. What will happen to the compass needle?

Study Guide for Quiz 5

In analyzing and understanding electrical circuits, several basic principles apply:

1. The current is the same everywhere along an unbroken path. At a junction, however, the total current leaving must equal the total current entering (“Kirchhoff’s junction rule”).
2. The voltage can only have a single value at any given point. Therefore if you imagine traveling around any loop of the circuit, the sum of all the voltage changes must be zero (“Kirchhoff’s loop rule”).
3. A battery normally acts as a source of fixed voltage (not fixed current).
4. Voltage doesn’t change (significantly) along ordinary wires, since they have very little resistance compared to other elements.
5. The change in voltage across a resistor is $\Delta V = IR$.
6. The change in voltage across a capacitor is $\Delta V = Q/C$.

You should be able to apply these principles to various circuits involving combinations of batteries, resistors, and capacitors. Important special cases include resistors in series, resistors in parallel, and the simple RC circuit.

You should have a good *qualitative* understanding of magnetic forces and fields. The magnetic field is another vector field, a bunch of little arrows living at every point in space.

Electrical currents *create* magnetic fields, with the direction determined by the “right-hand rule for sources”: Point the thumb of your right hand in the direction of the current; then your fingers curl around in the direction of the field.

Meanwhile, any moving electric charge feels a magnetic *force* due to the field, whose direction is determined by the “right-hand rule for forces”: Draw the current vector and the field vector tail-to-tail, then curl the fingers of your right hand from the current vector to the field vector (going around the short way); your thumb then points in the direction of the force.